



- ## CIRCUMSTANCES OF THE INVENTION

## DISCLOSURE & PUBLICATION PLANS (EXTREMELY IMPORTANT)

Public disclosure affects patent rights - Please answer diligently

9. If you have disclosed this invention to non-ASU personnel (including research sponsor) then indicate when, under what circumstances, and to whom. NO PUBLIC DISCLOSURE

- a. orally: \_\_\_\_\_
- b. in writing: \_\_\_\_\_
- c. by actual use, demonstration, or posters: \_\_\_\_\_

10. Have you submitted or do you plan to submit a report, abstract, paper, poster, or thesis relating to this invention for publication, for presentation at a conference, or to a research sponsor?

YES ☐

NO ☒

If yes, give details, including the actual or planned date of submission as well as expected time to acceptance. If a manuscript has been accepted, give the anticipated publication date. Append a copy of the latest draft manuscript available.

## THE INVENTION ITSELF AND ITS UTILITY

11. A. Brief summary of the invention:  
Include novel features and advantages. Describe possible commercial applications

SEE ATTACHED SHEETS

- B. Detailed description of the invention: Attach as many additional sheets as necessary.

SEE ATTACHED SHEETS



12. List companies you believe might be interested in using, developing or marketing this invention.

AXON TECHNOLOGIES CORPORATION

THIS INVENTION DISCLOSURE WILL NOT BE PROCESSED UNLESS THIS PORTION IS FILLED OUT COMPLETELY

13. Signatures, Names and addresses of Inventors

The undersigned agree to comply with ABOR policies on intellectual property and to execute suitable assignments of title if and when asked to do so.

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City/State/Zip	City/State/Zip
Home Telephone	Home Telephone
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**14. Technically Qualified Witnesses (Two Required)—invention disclosed to and understood by:**

a) \_\_\_\_\_  
Signature Date

\_\_\_\_\_  
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b) \_\_\_\_\_  
Signature Date

\_\_\_\_\_  
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*GROUP REVIEWED (KOZICKI, MITKOVA, YUN, ABERQUETTE)*

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Effective 10/1/98

## Optimized Electrodes for the Programmable Metallization Cell

### Electrode schemes for electrochemical microelectronic devices

Microelectronic devices based on electrochemical principles such as the Programmable Metallization Cell (PMC) require an oxidizable anode to promote rapid and stable electrodeposition. This means that for a silver-doped chalcogenide solid solution, the anode should contain silver. Silver has a tendency to thermally dissolve into the solid solution during thermal processing or over time in the completed device. This is undesirable as it alters device characteristics and so methods of reducing diffusion or reversing the effect are required. A related problem is unwanted or excessive electrodeposition on the cathode. This will tend to occur due to overwriting, particularly at low voltage, and following inadequate erase operations. Cathode "plating" may also occur spontaneously over time when supersaturated solid solutions are employed. A method of reversing this effect is needed otherwise the endurance/cycling of the devices will be greatly diminished. In addition, the redox potential for solid state electrochemical devices can be so low that they cannot be easily used in microelectronic circuits and systems which utilize relatively high supply voltages or operate with generous noise margins. A means for increasing the programming voltage is therefore desirable. Solutions to all of the above problems are addressed in this disclosure.

One way to achieve the goal of a thermally stable source of silver is to use an electrode formed by the intercalation of silver into a layer of a transition metal sulfide, e.g., tantalum sulfide ( $\text{TaS}_2$ ), thereby forming a  $\text{Ag}_x(\text{MS}_2)_{1-x}$  compound, where M is the transition metal in question. Note that in this system Ag acts like a simple pseudo-alkali metal but does not form hygroscopic intercalates. The  $\text{Ag}_x(\text{MS}_2)_{1-x}$  electrode can be fabricated in thin film form by physical vapor deposition so that it has an amorphous structure, thereby restricting the formation of channel-like paths in the layer.  $\text{TaS}_2$  can incorporate up to 66.8 atomic % of Ag ( $x = 0.668$ ) but the metal is localized in the  $\text{TaS}_2$  host material and so its thermal- or self-diffusion are greatly reduced. On the other hand, when an electric field is applied, the electrode acts as a source of  $\text{Ag}^+$  as the ionization potential of Ag is relatively low. Note that it is also likely that transition metal selenides would have similar characteristics and therefore may also be used in this context.

Silver compounds such as silver iodide (AgI) can also be utilized as a silver-supplying electrode. The  $\beta$  phase of AgI is a dielectric but the  $\alpha$  phase, which forms at temperatures over  $147^\circ\text{C}$ , has a high conductivity due to high silver mobility. It is one of the most desirable solid state electrolytes as it possesses the lowest known activation energy for conductivity. An additional advantage is that it is stoichiometric and does not require dopants to achieve its high conductivity. The carrier concentration is high since all of the  $\text{Ag}^+$  ions are potentially mobile but once again the silver will tend to stay in the material, even during thermal processing, until it is removed electrochemically.

Another approach is to include a layer which will slow down the outdiffusion of silver during fabrication but which is sufficiently porous to allow adequate amounts of Ag to come in contact with the solid solution by the time the device is fully processed. Thin films of germanium oxide between the silver anode and the solid solution are particularly good in this respect. Amorphous  $\text{GeO}_2$  is relatively porous and will "soak-up" silver during processing but it will greatly retard the thermal or photo-diffusion of silver into the solid solution. The metal in the oxide will allow it to conduct and the film becomes a good source of oxidizable silver. A particular advantage of germanium oxide is that it can be formed very readily on a germanium selenide solid electrolyte by exposing the chalcogenide to an oxidizing ambient at elevated temperature or in the presence of u.v. radiation of energy above the bandgap of the selenide. The oxide may also be vapor deposited using physical vapor deposition (from a solid  $\text{GeO}_2$  source) or chemical vapor deposition (from  $\text{GeH}_4 + \text{O}_2$  gas sources).

Yet another approach is to utilize "electrochemical control" of the silver in solution and on the electrodes. Silver may be taken out of solution and plated onto an electrode by applying a negative voltage in excess of the reduction potential. On the other hand, silver may be removed from an electrode and put into solution by applying a positive voltage above the oxidation potential. It is therefore possible to form a silver-containing electrode by electrochemically plating the silver from a supersaturated solid solution. The advantage of this is that the silver anode may be formed after the device has been completed, thereby avoiding the problem of silver diffusion from the anode during processing. This technique may also be used to control the concentration of silver in solution. If the silver concentration is above that required for device operation, plating it onto the anode using a "reverse bias" (the electrode which is the anode for write operations becomes the cathode during this) reduces the amount in solution. Alternatively, if the solid solution is metal-lean, silver may be added electrochemically from an anode with excess silver by applying an extended forward bias at a voltage near the reduction potential. Finally, in the case of a cathode which has a build-up of silver, it is possible to remove this using an extended reverse bias step. This is best done using a voltage which is close to the oxidation potential to prevent extended growth of an electrodeposit from the opposite electrode. Note that all of the above electrochemical controls may be employed repeatedly (if necessary) during device operation to maintain or enhance device performance.

With regard to control of programming voltage, a grown or deposited oxide between the cathode and the solid solution is a viable option. Unlike non-porous "hard" layers such as native oxides or nitrides of many common electrode materials, thin films of porous oxides such as  $\text{GeO}_2$  will allow silver to penetrate the film to provide a conducting pathway without breaking the film down. This oxide barrier results in a programming voltage which increases with the thickness of the layer. The writing voltage of the device therefore can be considerably

higher than that determined by the redox potential of the solid solution and the avoidance of breakdown means that the devices will cycle more reliably.

Basis of patent application and claims:

1. Use of silver-containing materials as thermally stable electrodes in PMC-like devices.
2. Use of Ag intercalated transition metal sulfides and selenides (e.g.,  $\text{TaS}_2$ ), and silver compounds (e.g., AgI).
3. Use of diffusion retarding layer between the Ag anode and the solid solution.
4. Use of  $\text{GeO}_2$  for silver diffusion control,
5. Formation of a silver-containing anode by the plating of silver from solid solution.
6. Control of silver concentration in solution by electrochemical deposition or dissolution.
7. Control/removal of silver from cathode by electrodisolution.
8. Reconditioning of devices by electrochemical deposition or dissolution during operation.
9. Use of porous materials for programming voltage control.
10. Use of  $\text{GeO}_2$  to increase the write voltage of a cell.
11. Formation of electrode layers by vapor deposition.

## **ADDENDUM to disclosures**

**M1-007: Optimiz d Electrodes for the Programmable Metallization Cell**

**M1-011: Ultra Low Energy Programmable Metallization Cell Devices**

The following applies to both of the above ASU disclosures and may be used to tie the subject matter together.

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When silver iodide is used as an anode in the Programmable Metallization Cell, unless excess silver is present within the material, the depletion of silver during electrodeposition will result in a loss of stoichiometry and a subsequent decrease in the electrodeposition reaction. To prevent this, the AgI layer could be placed between the solid solution and a silver containing electrode. The AgI barrier will help to prevent the thermal dissolution of silver into the solid solution but will not prevent the transport of silver during electrodeposition; its excellent properties as an electrolyte will allow it to act as a conduit for silver from a source which is not in direct contact with the solid solution. The high conductivity of the AgI layer will ensure that the on state of the device still has a sufficiently low resistance.

A major advantage of the interposition of a silver iodide layer between the solid solution and the anode metal relates to the increase in device efficiency which will be attained. When a voltage is applied to the device, the ions will drift to the cathode but electrons will also flow through the solid solution (toward the anode). The electrons which flow through the device are non-Faradaic, i.e., they do not take part in the electrodeposition process. These unproductive electrons represent wasted programming energy. AgI has an extremely high transport number (one of the highest known) - it essentially only conducts ions, not electrons. A silver iodide barrier will therefore practically eliminate electron transport through the device, thereby removing this wasteful current component and increasing device efficiency, potentially by many orders of magnitude.





Docket No.: M4065.0675/P675  
(PATENT)

**IN THE UNITED STATES PATENT AND TRADEMARK OFFICE**

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In re Patent Application of:  
John T. Moore, et al.

Application No.: 10/602,720

Group Art Unit: 2811

Filed: June 25, 2003

Examiner: Not Yet Assigned

For: PCRAM CELL OPERATION METHOD  
TO CONTROL ON/OFF RESISTANCE  
VARIATION

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**INFORMATION DISCLOSURE STATEMENT**

Commissioner for Patents  
Washington, DC 20231

Dear Sir:

Pursuant to 37 C.F.R. § 1.56, the attention of the Patent and Trademark Office is hereby directed to the documents listed on the attached PTO/SB/08. It is respectfully requested that the subject matter of the documents be expressly considered during the prosecution of this application and that the documents be made of record therein and appear among the "References Cited" on any patent to issue from this application. A copy of each document is attached.

**This Information Disclosure Statement is filed before the mailing date of a first Office Action on the merits as far as is known to the undersigned.**

A brief explanation of relevance of the non-(U.S.)-patent documents listed on form PTO/SB/08 is provided and attached hereto as Appendix A. The brief explanation provided for each document is not tantamount to an admission that a document is

“material” or that it qualifies as prior art. The Examiner is respectfully requested to utilize Appendix A only as a tool by which to better categorize the documents for substantive use in examining the claims of the application.

Documents discussed in Appendix A marked with an asterisk (\*) are indicated to be potentially more relevant than others. Such marking is provided only to assist the Examiner; however, the Examiner is requested to thoroughly review all documents cited herein.

In accordance with 37 C.F.R. § 1.97(g), the filing of this Information Disclosure Statement shall not be construed to mean that a search has been made or that no other material information as defined in 37 C.F.R. § 1.56(a) exists. It is submitted that the Information Disclosure Statement is in compliance with 37 C.F.R. § 1.98 and the Examiner is respectfully requested to consider and cite the listed documents.

The Commissioner is hereby authorized to charge any deficiency in the fees filed, asserted to be filed or which should have been filed herewith (or with any paper hereafter filed in this application by this firm) to our Deposit Account No. 04-1073, under Order No. M4065.0675.P675. A duplicate copy of this paper is enclosed.

Dated: November 4, 2003

Respectfully submitted,

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## APPENDIX A

U.S. Published Application No. 2003/0137869 to Kozicki: This document discloses in Fig. 4 and paragraph 68 a memory cell structure having a phase separated ion conductor 402, which includes high resistance portions 404 and low resistance portions 406.

U.S. Published Application No. 2003/0155589 to Campbell et al.: This document discloses a memory element formed as a stack of layers comprising a first electrode, a first chalcogenide glass, a silver-selenide layer, a second glass layer, and a second electrode.

Japanese patent application publication No. 56126916A by Akira: this published application generally relates to, *inter alia*, diffusing selenium with high accuracy into a chalcogenide with silver by use of photoresist and thermal treatment.

U.S. Patent No. 6,469,364 relates to a programmable interconnection system wherein a metal feature is created within the system by applying a voltage bias across the chalcogenide pathway. Voltages greater than 10 volts are applied to grow a metal dendrite and operating voltages are maintained below 5 volts to prevent unintentional growth of the metal dendrite. (col. 4 ln. 10-13).

\*U.S. Published Applicant No. 2002/0072188 to Gilton: this document generally discloses a programmable variable resistance memory cell in which at least a variable resistance layer of the cell is formed in an isolated stack in an insulative layer.

\* U.S. Published Applicant No. 2002/0123169 to Moore et al.: this document discloses a programmable variable resistance memory cell having a first conductive

layer 16 formed in an opening in a first dielectric layer, a second conductive layer 18 formed on the first conductive layer. A layer of a chalcogenide material is formed in an opening in a second dielectric layer aligned with the opening in the first dielectric layer so that the chalcogenide material is formed on and over the first and second conductive layers, and a third conductive layer 32 is formed over the layer of chalcogenide material. *See* paras. 22, 28 and Fig. 8.

\* U.S. Published Applicant No. 2002/0123248 to Moore et al.: this document discloses a programmable variable resistance memory cell having a first conductive layer 16 formed in an opening in a first dielectric layer, a second conductive layer 18 formed on the first conductive layer. A layer of a chalcogenide material is formed in an opening in a second dielectric layer aligned with the opening in the first dielectric layer so that the chalcogenide material is formed on and over the first and second conductive layers, and a third conductive layer 32 is formed over the layer of chalcogenide material. *See* paras. 22, 28 and Fig. 8.

U.S. Patent No. 5,177,567 to Klersy et al.: this document discloses a thin-film switching device having an electrode 1 formed on a substrate 7, a layer of insulating material 6 formed on the electrode 1, an opening formed in the insulating material to expose the electrode, a chalcogenide material 3 formed on the insulating material 6 and in the opening of the insulating material 6, a second electrode 5 on the chalcogenide material 3, and a second and thick layer of insulating material 2 is deposited at least around the peripheral surface of the chalcogenide material.

\* U.S. Patent No. 5,818,749 to Harshfield: this document discloses a reverse-biased diode memory array comprised of memory cells each having a structure changing memory element, such as chalcogenide resistors, coupled to an access device, such as a diode. *See, e.g.,* col. 6, lns. 36-47. Column 10, lines 12-59, *inter alia*, provides a

discussion on the effects of current leakage into the substrate during operation of a forward-biased diode memory, as compared with the operation of a reverse-biased diode memory in which very little current leaks into the substrate.

U.S. Patent No. 5,920,788 to Reinberg: this document discloses memory cells constructed by first thermally growing an SiO<sub>2</sub> layer 35 on a substrate having isolation trenches formed therein. Apertures 40 are formed in the SiO<sub>2</sub> layer 35, whereupon electrode contact layers 55 60 and 65 are deposited in the apertures 40. The SiO<sub>2</sub> layer is further grown and then apertures 70 are formed in the SiO<sub>2</sub> layer. Chalcogenide layer 75 is then deposited over the SiO<sub>2</sub> layer 35 and into the apertures 70. Upper electrode contact layers 80 and 85 are formed on the chalcogenide layer 75 to thereby complete the memory cells 90.

\*U.S. Patent No. 6,117,720 to Harshfield: this document generally discloses a plug-type stacked structure for a programmable variable resistance memory cell.

\*U.S. Patent No. 6,236,059 to Wolstenholme et al.: this document generally discloses a stacked structure for a programmable variable resistance memory structure 55 partially formed in an opening 50 in a dielectric layer.

\*U.S. Patent No. 6,300,684 to Gonzalez et al: this document discloses a programmable variable resistance memory cell 200 formed inside an opening 140, 215 formed in a substrate. *See, e.g.,* Figs. 14-15, col. 6, ln. 81 – col. 7, ln. 34.

\*Kozicki, U.S. Patent No. 6,487,106 (2002): this patent discloses two embodiments shown in Figs. 2 and 3 which include a barrier layer 250, 350, respectively, formed between the layer of conductive material (such as chalcogenide material) 240, 340, respectively and the electrode 230, 330, respectively. (See col. 5, lns. 12-24; col. 7, lns. 7-17). Fig. 5 discloses a structure 502 including an amorphous silicon

diode 570 formed adjacent to electrode 520, and a contact 560 formed adjacent the amorphous silicon diode 570.

\*Kozicki et al., U.S. Patent Application Publication No. 2002/0190350: this publication discloses in Figs. 5A, 6, 8 and 9 a structure having a substrate 510, 610, 810, 910; an insulating layer 520, 620, 820, 920; a bottom electrode 530, 630, 830, 930; an ion conductor 540, 640, 840, 940; a dielectric layer 550, 650, 850, 950; and a top electrode 560, 660, 860, 960. Fig. 5B discloses a structure having a bottom electrode 530, an ion conductor 540, an amorphous diode 562, and a top electrode 560.

\*Moore et al., U.S. Patent Application Publication No. 2003/0001229: this publication discloses in Fig. 8 a memory cell structure comprising a substrate 12, a dielectric layer 14, another dielectric layer 17 with an opening formed therein, a first metal layer 16 deposited in the opening, a second metal layer 18 formed on the first metal layer 16, an insulating layer 30 formed over the second dielectric layer 17 with an opening formed therein to expose the second metal layer 18, a metal-doped chalcogenide layer 27 formed in the opening in the insulating layer 30 and over the second metal layer 18, and an electrode 32 formed over the metal-doped chalcogenide layer 27. First metal layer 16 may be made from tungsten (paragraph 20) and the second metal layer 18 may be silver (paragraph 21).

\*Moore et al., U.S. Patent Application Publication No. 2002/0127886: this publication discloses in Fig. 6 a memory cell structure comprising a substrate 10, an insulating layer 11, a conductive layer 12, a metal layer 31, a glass material layer 51, and an electrode 61. Conductive layer 12 may be made from tungsten (paragraph 17) and the metal layer 31 may be silver (paragraph 19).

Moore et al., U.S. Patent Application Publication No. 2002/0123170: this publication discloses in Fig. 6 a memory cell structure which includes a substrate 10, an insulating layer 11, a conductive material 12, a dielectric layer 13, a metal ion-laced glass material 51, a layer of metal material 41, and an electrode 61.

\*Kozicki, U.S. Patent Application Publication No. 2003/0035314: this publication discloses a barrier layer 250, 350 as shown in Figs. 2 and 3 and discussed in paragraphs 35 and 45, respectively, formed between the layer of conductive material (such as chalcogenide material) 240, 340, respectively and the electrode 230, 330, respectively. Fig. 5 discloses a structure 502 including an amorphous silicon diode 570 formed adjacent to electrode 520, and a contact 560 formed adjacent the amorphous silicon diode 570, as discussed in paragraph 59.

\*Kozicki, U.S. Patent Application Publication No. 2003/0035315: paragraph 70 on page 7 and Fig. 1 disclose a contact 165 electrically coupled to electrode 120, and which may be formed of tungsten. Paragraph 82 on page 8 and Fig. 4 disclose a structure 400 including an amorphous silicon diode 470 formed adjacent to electrode 420, and a contact 460 formed adjacent the amorphous silicon diode 470. Paragraph 102 on page 11 and Figs. 27-28 disclose a common electrode 2710, ion conductors 2730 and 2735, second electrodes 2720 and 2725, and an insulating layer 2750. The insulating layer 2750 is a dielectric layer "that does not interfere with surface electrodeposit growth, such as silicon oxides, silicon nitrides, and the like."

U.S. Patent Application 2002/0168820, Kozicki et al., published November 14, 2002, at Page 6 and Fig. 1, discloses a method of forming a microelectronic programmable device having a chalcogenide ion conductor formed between two electrodes. This application further discloses forming a chalcogenide ion conductor "using thermal and/or

photo dissolution processing.” (Page 5). Read, write, and erase operations for a silver-germanium selenide glass are also disclosed. (Page 7).

PCT Application WO 02/21542, Kozicki et al., published March 14, 2002, at Page 15 and Fig. 1, discloses a method of forming a microelectronic programmable device having an chalcogenide ion conductor formed between two electrodes. This application further discloses forming a chalcogenide ion conductor using “thermal and/or photo dissolution processing.” (Page 11, lines 15-18). Read, write, and erase operations for a silver-germanium selenide glass are also disclosed. (Page 16, lines 10-30 and page 17, lines 1-26).

PCT Application WO 00/48196, Kozicki et al., published August 17, 2000, at Page 8, lines 20-30 and Fig. 1, discloses a method of forming a microelectronic programmable device having an chalcogenide ion conductor formed between two electrodes. This application further discloses forming a chalcogenide ion conductor using “thermal and/or photo dissolution processing.” (Page 7, lines 12-15). Read, write, and erase operations for a silver-germanium selenide glass are also disclosed. (Page 10, line 21 through page 12, line 8).

U.S. Patent 6,418,049, Kozicki et al, filed Dec. 4, 1997, at Column 4, lines 28-67, discloses a “programmable sub-surface aggregating metallization structure” having a chalcogenide ion conductor and a plurality of electrodes. This patent further discloses forming a chalcogenide ion conductor using a photo dissolution process. (Column 4, lines 48-60). Application of voltage to the structure is disclosed at column 5, line 59 through column 6, line 53; column 7, line 28 through column 8, line 36; column 10, lines 22-37; and column 11, lines 35-52.

U.S. Patent 5,761,115, Kozicki et al., filed May 30, 1996, at Columns 4-5, discloses a “programmable metallization cell” having a chalcogenide ion conductor and a plurality of electrodes. This patent further discloses forming a chalcogenide ion conductor using a photo dissolution process. (Column 5, lines 32-45).



Abdel-All, et al., Vacuum 59 (2000) 845-853: published in December, this document generally relates to, inter alia, the electrical properties of  $\text{Ge}_5\text{As}_{38}\text{Te}_{57}$  as a function of temperature.

\*Adler and Moss, J. Vac. Sci. Technol. 9 (1972) 1182-1189: this document generally relates to, inter alia, two types of electrical/material switching – threshold and memory, in amorphous materials; the effects of temperature, pressure, and frequency on switching; and the physics of threshold voltage and memory.

Adler et al., Ref. Mod. Phys. 50 (1978) 209-220: this document generally relates to, inter alia, threshold switching in amorphous alloys, state (“on” and “off”) characteristics, and glass properties.

Affi, et al., Appl. Phys. A 55 (1992) 167-169: this document generally relates to, inter alia, SeGe-Sb glasses.

\*Affi, et al., J. Phys. 17 (1986) 335-342: this document generally relates to, inter alia, electrical and thermal conductivity of  $\text{Ge}_x\text{Se}_{1-x}$  compositions as a function of temperature.  $\text{Ge}_{25}\text{Se}_{75}$  stoichiometry is disclosed.

Alekperova and Gadzhieva, 23 (1987) 137-139: this document generally relates to, inter alia, a characteristic diode state in  $\text{Ag}_2\text{Se}$  compositions upon heating (to 376-400°K).

\*Aleksiejunas and Cesnys, Phys. Stat. Sol. (a) 19 (1973) K169-K171: this document generally relates to, inter alia, the subjects of selenium investigation and how Se- $\text{Ag}_2\text{Se}$  contributes silver ions to a selenium composition.

Angell, Annu. Rev. Phys. Chem. 43 (1992) 693-717: this document generally relates to, inter alia, the presence of ion conductors in solids.

Aniya, Solid State Ionics 136-137 (November 2,2000) 1085-1089: this document generally relates to, inter alia, ion conductor glasses.

Asahara and Izumitani, J. Non-Cryst. Solids 11 (1972) 97-104: this document generally relates to, inter alia, Cu-As-Se glass.

Asokan, et al., Phys. Rev. Lett. 62 (1989) 808-810: this document generally relates to, inter alia,  $\text{Ge}_x\text{Se}_{100-x}$  glasses and their transition from semiconductor-like material to metal-like material.

\*Axon Technologies Corp., *Technology Description: Programmable Metallization Cell*: this believed publication generally relates to, inter alia, use of chalcogenides doped with metal much as silver or copper to create solid state switch with lower voltage requirement.

Baranovskii and Cordes, J. Chem. Phys. 111 (1999) 7546-7557: this document generally relates to, inter alia, ionic glasses and conduction (percolation theory).

Belin et al., Sol. St. Ionics 136-137 (November 2,2000) 1025-1029: this document generally relates to, inter alia, conductivity spectra of the glass  $0.5\text{Ag}_2\text{S}-0.5\text{GeS}_2$  and the temperature dependency of the conductivity.

Belin, et al., Solid State Ionics 143 (July 2, 2001) 445-455: this document generally relates to, inter alia, the electrical properties of  $\text{Ag}_7\text{GeSe}_5\text{I}$  – an argyrodite compound.

Benmore and Salmon, Phys. Rev. Lett. 73 (1994) 264-267: this document generally relates to, inter alia, the characteristics of chalcogenide alloys.

Bernede, Thin Solid Films 70 (1980) L1-L4: this document is in the French language and the Applicant has no translation. It is presently understood to generally relate to, inter alia, metal- $\text{Ag}_2\text{Se}$ -metal sandwich devices.

Bernede, Thin Solid Films 81 (1981) 155-160: this document generally relates to, inter alia, memories of selenium alloys with metal (e.g., Ag) electrodes, where the “on” memory states require constant voltage.

Bernede, Phys. Stat. Sol. (a) 57 (1980) K101-K104: this document generally relates to, inter alia, metal-Ag<sub>2</sub>Se-P systems.

Bernede and Abachi, Thin Solid Films 131 (1985) L61-L64: this document generally relates to, inter alia, metal-insulator-metal thin films with electroforming effects; the films have silver, gold and copper electrodes.

\*Bernede, et al., Thin Solid Films 97 (1982) 165-171: this document generally relates to, inter alia, Ag<sub>2</sub>Se/Se/Metal thin film sandwiches, which were studied by shape of electrodes (e.g., symmetrical or asymmetrical).

Bernede, et al., Phys. Stat. Sol. (a) 74 (1982) 217-224: this document generally relates to, inter alia, switching in Al-Al<sub>2</sub>O<sub>3</sub>Ag<sub>2-x</sub>Se<sub>1+x</sub> devices.

Bondarev and Pikhitsa, Solid State Ionics 70/71 (1994) 72-76: this document generally relates to, inter alia, Ag<sup>(-)</sup>/RbAg<sub>4</sub>I<sub>5</sub> boundary – depletion layer, and dendritic electrodeposition.

\*Boolchand, Asian Journal of Physics (2000) 9, 709-72: this document generally relates to, inter alia, Ge<sub>x</sub>Se<sub>1-x</sub> glasses, which have selenium-rich and germanium-rich clusters, and the intrinsically-broken bond characteristics thereof.

\*Boolchand and Bresser, Nature 410 (2001) 1070-1073: published April 26, this document generally relates to, inter alia, Ag<sub>2</sub>Se as an electrolyte additive to glass, e.g., GeSe<sub>4</sub>. Ge<sub>30</sub>Se<sub>70</sub> glass was found not to work well because of Ag<sub>2</sub>Se crystallization.

\*Boolchand, et al., J. Optoelectronics and Advanced Materials, 3 (September 2001), 703: this document generally relates to, inter alia, a review of Raman tool scattering

of chalcogenide glasses. The floppyness and rigidity is observed.  $\text{Ge}_x\text{Se}_{1-x}$  is disclosed, as is a stoichiometry of  $\text{Ge}_{25}\text{Se}_{75}$ .

\*Boolchand, et al., Properties and Applications of Amorphous Materials, M.F. Thorpe and Tichy, L. (eds.) Kluwer Academic Publishers, the Netherlands, 2001, pp. 97-132: this document generally relates to, inter alia, the prediction of glass rigidity in  $\text{Ge}_x\text{Se}_{1-x}$  glass, e.g.,  $\text{Ge}_{23}\text{Se}_{77}$ .

\*Boolchand, et al., Diffusion and Defect Data, Vol. 53-54 (1987) 415-420: this document generally relates to, inter alia, thermal annealing of  $\text{Ge}_x\text{Se}_{1-x}$  films.

\*Boolchand, et al., Phys. Rev. B 25 (1982) 2975-2978: this document generally relates to, inter alia, the examination of GeSe glass having Sn impurities by Mossbauer spectroscopy. Investigations into glass network topology, which has an intrinsically broken bond backbone, suggesting Ge and Se rich clusters.

Boolchand, et al., Sol. State Comm. 45 (1983) 183-185: this document generally relates to, inter alia,  $\text{Ge}_x\text{Se}_{1-x}$  and  $\text{Ge}_x\text{S}_{1-x}$  glasses.

\*Boolchand and Bresser, Dep. Of ECECS, Univ. Cincinnati 45221-0030: this document generally relates to, inter alia,  $\text{Ge}_x\text{Se}_{1-x}$  and the relation of glass transition temperature to Ge concentration in backbone. Although the publication date of this reference is not known to the Applicant, it was revised October 28, 1999 and is believed to be publicly available at the University of Cincinnati, Department of Electrical and Computer Engineering and Computer Science.

Boolchand and Grothaus, Eds. Chadi and Harrison, Proc. Int. Conf. Phys, Semicond., 17<sup>th</sup> (1985) 833-36: this document generally relates to, inter alia, GeSe and GeS glasses and the importance of a broken chemical order therein.

Bresser, et al., Phys. Rev. Lett. 56 (1986) 2493-2496: this document generally relates to, inter alia, an investigation of c-GeSe<sub>2</sub> structure.

Bresser, et al., J. de Physique 42 (1981) C4-193-C4-196: this document generally relates to, inter alia, the characteristics of  $\text{GeSe}_2$  and  $\text{GeS}_2$  glasses.

Bresser, et al., Hyperfine Interactions 27 (1986) 389-392: this document generally relates to, inter alia, germanium selenide glasses doped with tellurium.

Cahen, et al., Science 258 (1992) 271-274: this document generally relates to, inter alia, chalcopyrite  $\text{CuInSe}_2$  glasses.

Chatterjee, et al., J. Phys. D: Appl. Phys. 27 (1994) 2624-2627: this document generally relates to, inter alia,  $\text{As}_x\text{Te}_{100-x-y}\text{Se}_y$  glasses and the current, voltage, and electrical switching behavior. Discloses applicability in read mostly memories.

\*Chen and Tai, Appl. Phys. Lett. 37 (1980) 1075-1077: this document generally relates to, inter alia, silver photodoping of  $\text{Ge}_x\text{Se}_{1-x}$  and whisker formation (crystalline  $\text{Ag}_2\text{Se}$ ).

Chen and Cheng, J. Am. Ceram. Soc. 82 (1999) 2934-2936: this document generally relates to, inter alia, germanium containing chalcogenides doped with  $\text{Si}_3\text{N}_4$ .

Chen, et al., J. Non-Cryst. Solids 220 (1997) 249-253: this document generally relates to, inter alia,  $\text{As}_{10}\text{Ge}_{30}\text{Se}_{60}$  glasses (and the like) doped with  $\text{Si}_3\text{N}_4$ .

Cohen, et al., J. Non-Cryst. Solids 8-10 (1972) 885-891: this document generally relates to, inter alia, Ge-Te-X glasses as memory devices.

Croitoru, et al., J. Non-Cryst. Solids 8-10 (1972) 781-786: this document generally relates to, inter alia, the physics of conductivity in Ge-containing films.

Dalven and Gill, J. Appl. Phys. 38 (1967) 753-756: this document generally relates to, inter alia, beta- $\text{Ag}_2\text{Te}$ .

Davis, Search 1 (1970) 152-155: this document generally relates to, inter alia, the subject of amorphous semiconductors as compared to glass.

\*Dearnaley, et al., Rep. Prog. Phys. 33 (1970) 1129-1191: this document generally relates to, inter alia, background information about glass and memory.

\*Dejus, et al., J. Non-Cryst. Solids 143 (1992) 162-180: this document generally relates to, inter alia, Ag-Ge-Se glass with Ag primarily bonded to Se. The reference discloses glass preparation.

den Boer, Appl. Phys. Lett. 40 (1982) 812-813: this document generally relates to, inter alia, a-Si:H sandwich structures and threshold switching from a low to high conductance.

Drusedau, et al., J. Non-Cryst. Solids 198-200 (1996) 829-832: this document generally relates to, inter alia, work with a-Si:H multilayers optoelectrical properties.

El Bouchairi, et al., Thin Solid Films 110 (1983) 107-113: this document generally relates to, inter alia,  $\text{Ag}_{2-x}\text{Se}_{1+x}$  thin film electrical characteristics and metal-like conduction.

El Gharras, et al., J. Non-Cryst. Solids 155 (1993) 171-179: this document generally relates to, inter alia, photoconductivity of amorphous Se and Ge-Se alloy evaporated films, and reduction of photocurrent by increase of Ge content.

\*El Ghrandi, et al., Thin Solid Films 218 (1992) 259-273: this document generally relates to, inter alia, GeSe films deposited by PECVD, Ag evaporation deposition onto glass and photodissolution into same, and optical properties are investigated. GeSe stoichiometries of 30/70 and 25/75, respectively, are disclosed.

\*El Ghrandi, et al., Phys. Stat. Sol. (a) 123 (1991) 451-460: this document generally relates to, inter alia, dissolution of Ag into  $\text{GeSe}_{5.5}$  glass by flash evaporation.

El-kady, Indian J. Phys. 70 A (1996) 507-516: this document generally relates to, inter alia,  $\text{Ge}_{21}\text{Se}_{17}\text{Te}_{62}$  glass and memory, switching, and current controlled negative resistance.

Elliott, J. Non-Cryst. Solids 130 (1991) 85-97: this document generally relates to, inter alia, mechanisms of photodissolution of metals (e.g., Ag) in chalcogenides based on ionic and electronic charge carriers.

\*Elliott, J. Non-Cryst. Sol. 130 (1991) 1031-1034: this document generally relates to, inter alia, the photodissolution of metals (e.g., Ag) in chalcogenide glasses and the physics thereof.

Elsamanoudy, et al., Vacuum 46 (1995) 701-707: this document generally relates to, inter alia, studies of quaternary chalcogenide films with Te-As-Ge-Si sandwich structures between electrodes.

\*El-Zahed and El-Korashy, Thin Solid Films 376 (November 1,2000) 236-240: this document generally relates to, inter alia,  $\text{Ge}_{20}\text{Bi}_x\text{Se}_{80-x}$  film analysis regarding conduction and changes from p to n type.

Fadel, Vacuum 44 (1993) 851-855: this document generally relates to, inter alia, a study of the switching and memory characteristics of  $\text{Se}_{75}\text{Ge}_{25-x}\text{As}_x$  films.

\*Fadel and El-Shair, Vacuum 43 (1992) 253-257: this document generally relates to, inter alia,  $\text{Se}_{75}\text{Ge}_7\text{Sb}_{18}$  glass electrical conduction and thermal character.

Feng, et al., Phys. Rev. Lett. 78 (1997) 4422-4425: this document generally relates to, inter alia, germanium selenide and germanium sulfide materials.

\*Feng, et al., J. Non-Cryst. Solids 222 (1997) 137-143: this document generally relates to, inter alia, the structural character of  $\text{Ge}_x\text{S}_{1-x}$  glass, e.g., hardness and elasticity.

\*Fischer-Colbrie, et al., Phys. Rev. B 38 (1988) 12388-12403: this document generally relates to, inter alia, photodiffused Ag-GeSe<sub>2</sub> and the interaction between doped Ag with Se atoms and Ge with Ge atoms.

Fleury, et al., Phys. Stat. Sol. (a) 64 (1981) 311-316: this document generally relates to, inter alia, amorphous selenium films and their conductance.

Fritzsche, J. Non-Cryst. Sol. 6 (1971) 49-71: this document generally relates to, inter alia, background information on chalcogenides as semiconductors.

Fritzsche, Annual Review of Mat. Sci. 2 (1972) 697-744: this document generally relates to, inter alia, background information on amorphous semiconductors.

Gates, et al., J. Am. Chem. Soc. (2001): this document generally relates to, inter alia, creating Ag<sub>2</sub>Se nanowires by chemical reaction.

Gosain, et al., Jap. J. Appl. Phys. 28 (1989) 1013-1018: this document generally relates to, inter alia, germanium telluride glasses sandwiched in electrodes and the physics thereof.

\*Guin et al., J. Non-Cryst. Sol. 298 (March 28, 2002) 260-269: this document generally relates to, inter alia, germanium selenide (GeSe) glass with low hardness, the mechanical properties of which are investigated. Stoichiometries of the glass are disclosed as being, inter alia, 10/90, 20/80, and 30/70, respectively.

\*Guin et al., J. Am. Ceram. Soc. 85 (June 2002) 1545-1552: this document generally relates to, inter alia, germanium selenide glasses and a study of the hardness properties thereof. Glass stoichiometries of 40/60 and 20/80, respectively, are disclosed.

Gupta, J. Non-Cryst. Sol. 3 (1970) 148-154: this document generally relates to, inter alia, switching in chalcogenides.



Haberland and Stiegler, J. Non-Cryst. Solids 8-10 (1972) 408-414: this document generally relates to, inter alia, glasses containing Te, As, Ge, and Si, and pulse sequence and time factors in switching.

Haifz, et al., J. Apply. Phys. 54 (1983) 1950-1954: this document generally relates to, inter alia, As-Se-Cu glasses.

Hajto, et al., Int. J. Electronics 73 (1992) 911-913: this document generally relates to, inter alia, metal/a-Si:H/metal devices.

Hajto, et al., J. Non-Cryst. Solids 266-269 (May 1,2000) 1058-1061: this document generally relates to, inter alia, a-Si:H ion conductors, polarity-dependant digital and analogue memory, and dependency on contact metals.

Hajto, et al., J. Non-Cryst. Solids 198-200 (1996) 825-828: this document generally relates to, inter alia, electroformed V/a-Si:H/Cr devices.

Hajto, et al., Phil. Mag. B 63 (1991) 349-369: this document generally relates to, inter alia, p+ type amorphous Si memory structures with polarity dependent analogue switching.

Hayashi, et al., Japan. J. Appl. Phys. 13 (1974) 1163-1164: this document generally relates to, inter alia, Au-CdS(CdSe)-Au systems and metal-Se-Sn-SnO<sub>2</sub> systems.

\*Hegab, et al., Vacuum 45 (1994) 459-462: this document generally relates to, inter alia, Ge<sub>20</sub>M<sub>75</sub>Sb<sub>18</sub> glass electrical conduction and thermal character.

Helbert et al., SPIE Vol. 333 Submicron Lithography (1982): this publication generally relates to, inter alia, hybrid ultragraphic process using both electron beam and conventional optical exposure within the same device level with a photoresist.

Hilt, dissertation (1999): this publication generally relates to, inter alia, stability of chalcogenides such as  $\text{Ge}_x\text{Se}_{1-x}$  with Ag doping by photodissolution and thermal diffusion.

Hirose et al., Phys. Stat. Sol. (1980): this publication generally relates to, inter alia, switch and memory phenomena in amorphous  $\text{As}_2\text{S}_3$  with photo-doped Ag, including new mechanism, electrical reliability, rapid memory performance, thermal characteristics and durability.

Hirose and Hirose, J. Appl. Phys. 47 (1976) 2767-2772: this document generally relates to, inter alia, Ag photodoped  $\text{As}_2\text{S}_3$ , polarized switching, and dendrite formation.

Holmquist et al., 62 J. Amer. Ceram. Soc., No. 3-4 (March-April 1979): this publication generally relates to, inter alia, reactions and diffusion of Ag in arsenic chalcogenide glass below the glass transition temperature, including solubility information and concentration dependence of Ag diffusion in these glasses.

Hong and Speyer, J. Non-Cryst. Solids 116 (1990) 191-200: this document generally relates to, inter alia, Cd-Ge-As glass with Ag contacts.

Hosokawa, J. Optoelectronics and Advanced Materials 3 (2001) 199-214: this document generally relates to, inter alia, x-ray scattering experiments on glassy  $\text{Ge}_x\text{Se}_{1-x}$ .

Hu, et al., J. Non-Cryst. Solids 227-230 (1998) 1187-1191: this document generally relates to, inter alia, a-Si:H with Cr and V electrodes.

Hu, et al., Phil. Mag. B. 74 (1996) 37-50: this document generally relates to, inter alia, a-Si:H glasses doped with Cr and analogue memory.

Hu, et al., Phil. Mag. B 80 (January 1, 2000) 29-43: this document generally relates to, inter alia, a-Si:H films doped with Cr-p+.

Huggett et al., 42 Appl. Phys. Lett., No. 7 (April 1983): this publication generally relates to, inter alia, reactive sputter etching to develop silver-sensitized  $\text{Ge}_x\text{Se}_{1-x}$  photoresist.

Iizima, et al., Solid State Comm. 8 (1970) 153-155: this document generally relates to, inter alia, switching and memory effects in As-Te- $\text{I}^{1,2}$  and As-Te-Ge- $\text{Si}^3$  glass systems. Thermal breakdown is proposed switching effect.

Ishikawa and Kikuchi, J. Non-Cryst. Solids 35 & 36 (1980) 1061-1066: this document generally relates to, inter alia,  $\text{Ge}_2\text{S}_2$  films with Ag photodissolved therein.

\*Iyetomi, et al., J. Non-Cryst. Solids 262 (February 2000) 135-142: this document generally relates to, inter alia, Ag/Ge/Se glasses as a composite of  $\text{GeSe}_2$  and  $\text{Ag}_2\text{Se}$  (a fast ion conductor) and polarizability of Se ions.

Jones and Collins, Thin Solid Films 40 (1977) L15-L18: this document generally relates to, inter alia, switching in Se films and switching back with reverse pulse.

Joullie and Marucchi, Phys. Stat. Sol. (a) 13 (1972) K105-K109: this document generally relates to, inter alia,  $\text{As}_2\text{Se}_7$  glass.

Joullie and Marucchi, Mat. Res. Bull. 8 (1973) 433-442: this document generally relates to, inter alia,  $\text{As}_2\text{Se}_5$  film conduction and switching.

Kaplan and Adler, J. Non-Cryst. Solids 8-10 (1972) 538-543: this document generally relates to, inter alia, thermal effects on semiconductor switching.

Kawaguchi et al., 164-166 J. Non-Cryst. Solids (1993): this publication generally relates to, inter alia, deposition mechanism of Ag particles on Ag-rich Ag-As-S glass from a view-point of electrical effects.

\*Kawaguchi, et al., J. Appl. Phys. 79 (1996) 9096-9104: this document generally relates to, inter alia, Ag-rich chalcogenide glass,  $\text{Ge}_3\text{S}_7\text{-Ag}$  and  $\text{Ge}_{30}\text{Se}_{70}\text{-Ag}$ , max Ag content of 67%, graphs phase diagram, and discloses that Ag works better than Cu.

\*Kawaguchi and Masui, Jpn. J. Appl. Phys. 26 (1987) 15-21: this document generally relates to, inter alia, silver photodoping of chalcogenide films, e.g.,  $\text{Ge}_{30}\text{Se}_{70}$  films.

\*Kawasaki, et al., Solid State Ionics 123 (1999) 259-269: this document generally relates to, inter alia, the electrical properties of  $\text{Ag}_x(\text{GeSe}_3)_{1-x}$ , conductivity EMF measurements, glass composition, X-ray diffraction,  $T_g$  and  $T_c$ , Ag ion transport, and glass structure.

\*Kluge, et al., J. Non-Cryst. Solids 124 (1990) 186-193: this document generally relates to, inter alia, photodiffusion of silver into  $\text{Ge}_x\text{Se}_{100-x}$  layers, how this differs from ion beam induced diffusion,  $\text{Ge}_{30}\text{Se}_{70}$  stoichiometry,  $\text{Ag}_2\text{Se}$ , and percolation threshold.

\*Kolobov, J. Non-Cryst. Solids 198-200 (1996) 728-731: this document generally relates to, inter alia, p-type conductive chalcogenides, materials, and physics thereof.

\*Kolobov, J. Non-Cryst. Solids 137-138 (1991) 1027-1030: this document generally relates to, inter alia, doped and undoped glass layers as a p-n junction.

\*Kolobov and Elliott, Advances in Physics (1991): this publication generally relates to, inter alia, photodoping (photodiffusion/photodissolution) of amorphous chalcogenides by metals, particularly silver.

Korkinova and Andreichin, J. Non-Cryst. Solids 194 (1996) 256-259: this document generally relates to, inter alia, polarization of chalcogenide glass as depending on the materials used for electrode contacts.

\*Kotkata, et al., Thin Solid Films 240 (1994) 143-146: this document generally relates to, inter alia, GeSe glass switching and film thickness, memory, current filament, chemical and mechanical switching properties, and discloses that heat treatment or aging improves switching.

\*Kozicki and Mitkova, Proceedings of the XIX International Congress on Glass, Society for Glass Technology (2001): this publication generally relates to, inter alia, the physical effects of introduction of Ag into chalcogenide glasses, where introduction is by photodiffusion.

\*Michael N. Kozicki, Programmable Metallization Cell Technology Description, February 18, 2000: this publication generally relates to, inter alia, programmable metallization cells (PMC) for storing memory as resistive states. The PMC cells use a chalcogenide glass region bounded by electrodes as a memory device. The chalcogenide glass can be germanium selenide. The electrodes can be an oxidizable and indifferent material. Multiple-bit cells are disclosed; relying on controlling an amount of electrodeposit. Barrier layers of metal oxides, isolation diodes, and access transistors are also disclosed.

\*Michael N. Kozicki, Axon Technologies Corp. and Arizona State University, Presentation to Micron Technology, Inc., April 6, 2000: this publication generally relates to, inter alia, programmable metallization cells (PMC) for storing memory as resistive states and operating parameters for PMC devices.

\*Kozicki et al., Proceedings of the 1999 Symposium on Solid State Ionic Devices (1999): this publication generally relates to, inter alia, physical and electrical characteristics of metal doped chalcogenide films (photodoped  $\text{Ag}_4\text{As}_2\text{S}_3$ ) between electrodes, useful in memories, configurable connections, and self-repairing interconnections.

\*Kozicki et al., Superlattices and Microstructures, 27 (2000): this publication generally relates to, inter alia, solid solutions of metals (e.g., silver) in arsenic trisulfide and their physical and electrical characteristics.

\*Kozicki et al., Microelectronic Engineering, vol. 63/1-3 (2002): this publication generally relates to, inter alia, the photodiffusion of Ag into germanium selenide glass films, the amount of Ag that can be incorporated in to such a film by photodiffusion, and the characteristics of the resulting doped films.

Lakshminarayan, et al., J. Instn. Electronics & Telecom. Engrs. 27 (1981) 16-19: this document generally relates to, inter alia, tellurium-containing chalcogenide glasses.

Lal and Goyal, Indian Journal of Pure & Appl. Phys. 29 (1991) 303-304: this document generally relates to, inter alia, theory on chalcogenide switching.

\*Leimer et al., Phys. Stat. Sol. (a) 29 (1975) K129-K132: this document generally relates to, inter alia, germanium selenide glass polarization behavior, e.g., inductive and capacitive components.

\*Leung, et al., Appl. Phys. Lett. 46 (1985) 543-545: this document generally relates to, inter alia, photoinduced diffusion of Ag into  $\text{Ge}_x\text{Se}_{1-x}$  and techniques for same.

Matsushita, et al., Jap. J. Appl. Phys. 11 (1972) 1657-1662: this document generally relates to, inter alia, Se-SnO<sub>2</sub> film switching and reversibility.

Matsushita, et al., Jpn. J. Appl. Phys. 11 (1972) 606: this document generally relates to, inter alia, polarized memory effect in Se films.

Mazurier, et al., Journal de Physique IV 2 (1992) C2-185 - C2-188: this document generally relates to, inter alia, Te-based glasses.

McHardy et al., 20 J. Phys. C.: Solid State Phys. (1987): this publication generally relates to, inter alia, sensitivity and high resolution of metals in amorphous chalcogenides by electron and UV radiation.

Messoussi, et al., Mat. Chem. And Phys. 28 (1991) 253-258: this document generally relates to, inter alia, selenium films and Bi electrodes.

\*Mitkova and Boolchand, J. Non-Cryst. Solids 240 (1998) 1-21: this document generally relates to, inter alia, the analysis of Group IV and V chalcogenides.

\*Mitkova and Kozicki, J. Non-Cryst. Solids 299-302 (May 14, 2002) 1023-1027: this document generally relates to, inter alia, photodissolution of Ag into Se-rich Ge-Se glasses for use in memory devices. The information disclosed in this reference was available to and known by the inventors prior to the filing of the application.

\*Mitkova, et al., Phys. Rev. Lett. 83 (1999) 3848-3851: this document generally relates to, inter alia, Ag doped chalcogenides,  $\text{Ge}_{20}\text{Se}_{80}$  stoichiometry is disclosed, Se rich glasses, Ge rich glasses, stoichiometric glasses, and presence of  $\text{Ag}_2\text{Se}$ .

\*Miyatani, J. Phys. Soc. Japan 34 (1973) 423-432: this document generally relates to, inter alia, electrical and ionic properties of solid solutions (e.g., doped glass), polarization, conductivity,  $\text{Ag}_2\text{Se}$  and  $\text{Cu}_2\text{Se}$ .

Miyatani, J. Phys. Soc. Japan 13 (1958) 317: this document generally relates to, inter alia, experiments regarding the electronic conductivity, ionic conductivity, hall constant, thermoelectric power, and Nernst coefficient of  $\text{Ag}_2\text{Se}$  as function of the e.m.f., E, the galvanic cell, or the deviation from stoichiometric composition.

\*Miyatani, J. Phys. Soc. Japan 14 (1959) 996-1002: this document generally relates to, inter alia,  $\text{Ag}_2\text{Te}$  and  $\text{Ag}_2\text{Se}$  ion conduction and the chemical potential of silver ions.

Mott, J. Non-Cryst. Sol. 1 (1968) 1-17: this document generally relates to, inter alia, glasses with vanadium or iron.

\*Nakayama, et al., Jpn. J. Appl. Phys. 32 (1993) 564-569: this document generally relates to, inter alia, electrically erasable nonvolatile memories in chalcogenide films of  $\text{As}_x\text{Sb}_y\text{Te}_z$ , flash evaporative deposition techniques, a high set-voltage compared to read-voltage,  $V_t$  creates a “filament,” and refresh-type pulse.

\*Nakayama, et al., Jpn. J. Appl. Phys. 39 (November 15, 2000) 6157-6161: this document generally relates to, inter alia, phase transition random access memory (PRAM) made of chalcogenide glass.

\*Nang et al., Jap. J. App. Phys. 15 (1976) 849-853: this document generally relates to, inter alia,  $\text{Ge}_x\text{Se}_{1-x}$  electrical and optical properties; it also discloses  $\text{Ge}_{.80}\text{Se}_{.20}$ ,  $\text{Ge}_{.60}\text{Se}_{.40}$ , and  $\text{Ge}_{.50}\text{Se}_{.50}$ .

Narayanan, et al., Phys. Rev. B 54 (1996) 4413-4415: this document generally relates to, inter alia, chalcogenide glass switching as thermally originated.

\*Neale and Aseltine, , IEEE Transactions On Electron Dev. Ed-20 (1973) 195-209: this document generally relates to, inter alia, read mostly memories with chalcogenides (e.g., Ge, Te), also discloses “floating gate,” and material combinations including Ge and Se.

Ovshinsky and Fritzsche, Metallurgical Transactions 2 (1971) 641-645: this document generally relates to, inter alia, reversible changes in amorphous Si, Be, and B using a laser to write and erase.

Ovshinsky, Phys. Rev. Lett. 21 (1968) 1450-1453: this document generally relates to, inter alia, rapid and reversible resistive switching by electric field in amorphous semiconductors.



Owen, et al., IEE Proc. 129 (1982) 51-54: this document generally relates to, inter alia, a-Si:H, gold or aluminum dots and silver paste.

Owen, et al., Phil. Mag. B 52 (1985) 347-362: this document generally relates to, inter alia, photoinduced chalcogenide effects ( $\text{As}_2\text{S}_3$ ) both reversible and irreversible.

\*Owen, et al., Int. J. Electronics 73 (1992) 897-906: this document generally relates to, inter alia, threshold and memory switching a-Si:H ion conductor, polarity-dependant digital memory, analogue memory, and device operation dependency on metal contacts.

Owen et al., Nanostructure Physics and Fabrication (1989): this publication generally relates to, inter alia, photo-induced structural or physico-chemical changes of amorphous chalcogenides when exposed to light/irradiation, affecting chemical solubility.

Pearson and Miller, App. Phys. Lett. 14 (1969) 280-282: this document generally relates to, inter alia, glass diodes.

\*Pinto and Ramanathan, Appl. Phys. Lett. 19 (1971) 221-223: this document generally relates to, inter alia, electric field inducement of glass switching “filamentary” path.

Popescu, Solid-State Electronics 18 (1975) 671-681: this document generally relates to, inter alia, the physics of chalcogenide switching.

Popescu and Croitoru, J. Non-Cryst. Solids 8-10 (1972) 531-537: this document generally relates to, inter alia, switching behavior and thermal instability in chalcogenide glasses.

Popov, et al., Phys. Stat. Sol. (a) 44 (1977) K71-K73: this document generally relates to, inter alia, investigations into threshold and memory switching effects in amorphous selenium with electrodes of Ca, Ni, Ag, and Al.

\*Prakash, et al., J. Phys. D: Appl. Phys. 29 (1996) 2004-2008: this document generally relates to, inter alia, switching of  $\text{Ge}_{10}\text{As}_{45}\text{Te}_{45}$  glass, study of threshold voltage concept and switch back to off, suitability for read mostly memory.

Rahman and Sivarama, Mat. Sci. Eng. B12 (1992) 219-222: this document generally relates to, inter alia, chalcogenide glass with no exothermic crystallization reaction above  $T_g$  being of a threshold-switching type.

\*Ramesh, et al., Appl. Phys. A 69 (1999) 421-425: this document generally relates to, inter alia, electrical switching in GeTe with Ag or Cu and thermal character investigations.

Rose, et al., J. Non-Cryst. Solids 115 (1989) 168-170: this document generally relates to, inter alia, a-Si with Cr or V contacts.

Rose et al., Mat. Res. Soc. Symp. Proc. V258 (1992) 1075-1080: this document generally relates to, inter alia, a-Si:H memory.

Schuoocker and Rieder, J. Non-Cryst. Solids 29 (1978) 397-407: this document generally relates to, inter alia, As-Te-Ge film sandwiches with Molybdenum electrodes.

Sharma and Singh, Proc. Indian Natn. Sci. Acad. 46, A, (1980) 362-368: this document generally relates to, inter alia, evaporated Se films and their electrical conductivity.

\*Sharma, Ind. J. Of Pure and Applied Phys. 35 (1997) 424-427: this document generally relates to, inter alia, n-type  $\text{Ag}_2\text{Se}$  and other material stoichiometries. The device conductivity is analyzed, as is the grain size as a factor in device ability to polarize.

Shimizu et al., 46 B. Chem Soc. Japan, No. 12 (1973): this publication generally relates to, inter alia, electric conductivity increase by increasing Ag-photodoping of chalcogenide glass.

Snell, et al., J. Non-Cryst. Solids 137-138 (1991) 1257-1262: this document generally relates to, inter alia, a-Si:H analogue memory by applying voltages of increasing magnitude.

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